

KINETIC AND SUBJECTIVE ANALYSIS OF KNEE ROLLERS, HANDS FREE CRUTCH, AND CONVENTIONAL CRUTCHES

Dylan T. Lange, Martesia M. Neal, Casey I. Takahashi, Josh J. Reisimer,
Alyssa M. Stockero, and William P. Ebben

Biomechanics Research Unit, Exercise Science Research Laboratory,
Lakeland University, Plymouth, WI

This study assessed the kinetic demands and the subject's perceptions of ambulatory assistance devices. Twenty-two subjects used a knee roller (KR), a hands free crutch (HFC), and conventional axillary crutches (CC), while walking over a force platform. Peak ground reaction forces (pGRF) were obtained for each device for the un-affected and the affected limb. Significant differences in pGRF for each device were found for each limb ($p \leq 0.001$). No gender interaction was found ($p > 0.05$). The pGRF of the un-affected limb was highest for the CC and lowest for the KR ($p \leq 0.05$). The pGRF of the affected limb was higher for the KR compared to the HFC ($p = .045$). For the un-affected limb, the CC produced 45% more kinetic demand than the KR, and 11% more than the HFC. The qualitative analysis suggested that the CC and KR were favored over the HFC.

Keywords: Ambulatory aids, force, locomotion, sports rehabilitation

INTRODUCTION: A variety of ambulatory assistance devices are available to practitioners and the athletes who they rehabilitate. Research has evaluated some of these devices, assessing a variety of outcome variables in order to further understand the demands and potential value of each.

Studies have compared two (Alkjaer, Larsen, Pedersen, Nielsen, & Simonsen, 2006; Kocher, Chalupa, Lopez, & Kirk, 2016), three (Hardi, Bridenbaugh, Gschwind, & Kressig, 2014; Patel, Batten, Robertson, Enki, Wansbrough, & Davis, 2016; Saensook, Phonthee, Srisim, Mato, Warranapan, & Amarachaya, 2013; Van Lieshout, Stukstette, De Bie, VanWanseele, & Pisters, 2016) and four devices (Youdas, Kotajarvi, Padgett, & Kaufman, 2005). The devices assessed in these studies included traditional axillary crutches (Hardi et al., 2014; Kocher et al., 2016; Patel et al., 2016; Saensook et al., 2013; Youdas et al., 2005), wheeled knee rollers (Alkjaer et al., 2006; Kocher et al., 2016; Patel et al., 2016; Youdas et al., 2005), single point canes (Hardi et al. 2014; Saensook et al., 2013; Youdas et al., 2005), walking frame or walker (Patel et al., 2016; Saensook et al., 2013), forearm crutches (Youdas et al., 2005) and the hands free crutch (Rambani, Shahid, & Goyal, 2007).

A variety of outcome variables were assessed during the comparison of these devices, including walking and spatiotemporal gait patterns (Alkjaer et al., 2006; Hardi et al., 2014), walking speed and distance (Saensook et al., 2013), perceived exertion (Kocher et al., 2016), energy consumption (Patel et al., 2016), the ground reaction force (GRF) differences in response to biofeedback (Van Lieshout et al., 2016), and the role of these devices on in-patient treatment duration (Rambani et al., 2007). There also exists a literature review which described how select ambulatory assistance devices enabled activity among adults with physical disabilities (Bertrand, Raymond, Miller, Martin Ginis, & Demers, 2017).

The kinetic and subjective demands of using select ambulatory assistance devices has also been described (Bertrand et al., 2017). However, in comparison to other outcome variables, the kinetics of ambulatory assistance devices has not been frequently studied. This is particularly true for hands free crutches. Novel devices such as hands-free crutches have been described in the literature, including the quasi-experimental cost-benefit analysis of their use and their effect on the duration of in-patient stay (Rambani et al., 2007).

The subjective experience of using ambulatory assistance devices has also not been examined, other than to quantify the ratings of perceived exertion (Kocher et al., 2016). Furthermore, previous research has not assessed gender differences associated with the use of these devices. Therefore, the purpose of this study was to assess the kinetic demands

of three ambulatory assistance devices and to determine if there are gender differences in response to the use of each. This study also sought to assess the user's subjective perceptions associated with the use of each device.

METHODS: This study used a mixed-methods design which included a randomized repeated measures quantitative and interview-based qualitative aspects. Independent variables included the ambulatory assistance devices assessed in this study and gender. Dependent variables included the peak ground reaction force (pGRF) for each device for the un-affected limb (left) and the affected limb (right) as well as the numerically scaled subjective assessment provided by the subjects.

Subjects included a population-based healthy volunteer sample of 12 men (age = 22.68 ± 9.61 years, height = 178.44 ± 8.26 cm, weight = 84.17 ± 14.72 kg) and 10 women (age = 20.00 ± 0.94 years, height = 167.13 ± 6.00 cm, weight = 79.81 ± 22.30 kg). Thirteen of 22 subjects had experience using conventional axillary crutches (CC), while none of the subjects has previously used the knee roller (KR) or hands free crutch (HFC). Subjects provided written informed consent, and the study was approved by the Institutional Review Board.

Subjects were assessed using three ambulatory assistance devices including the KR, HFC, and CC. Subjects walked across the force platform (Accupower, Advanced Mechanical Technologies Incorporated, Watertown, MA, USA) in three conditions. These included only the affected limb making contact, only the un-affected limb making contact, or both limbs making contact. Subjects walked at volitional gait speed, consistent with previous research recommendations (Youdas et al., 2005; Van Lieshout et al, 2016). Each ambulatory assistance device was deployed according to manufacturer recommendations, and the axillary crutch length, for each subject, was based on published recommendations (Obediya, Adeagbo, & Gboyega, 2016). Participants performed two repetitions in each test condition and rested one-minute between each test exercise and all repetitions. The force platform was calibrated prior to the testing session. Peak GRF data were acquired at 600hz and analyzed in real time with proprietary software (Accupower, Advanced Mechanical Technologies Incorporated, Watertown, MA, USA). The pGRF for the affected limb was calculated minus the GRF of the devices.

Subjects were also interviewed to determine their subjective assessment of each device, based on a survey created and validated for this study. Answers to open-ended questions were content analyzed according to methods previously described (Patton, 1990). The researchers were trained and experienced with these qualitative methods and content analysis. A three-way repeated measures ANOVA determined differences in subject pGRF across all device conditions and the interaction between device condition and gender. Bonferroni post-hoc analysis identified specific differences between the devices. The trial-to-trial reliability was assessed using average measures intraclass correlation coefficients (ICC). Deductive and inductive content analysis was used to evaluate the qualitative data regarding the subject's experience with each device. Each researcher generated raw data and higher order themes via independent, inductive content analysis and compared these independently generated themes until consensus was reached at each level of analysis.



Figure1. Kinetic assessment of an athlete using conventional axillary crutches, hands free crutch, and knee roller.

RESULTS: Significant differences in pGRF were found for the un-affected limb ($p \leq 0.001$, $\eta_p^2 = .77$, $d = 1.00$) and affected limb ($p \leq 0.001$, $\eta_p^2 = .85$, $d = 1.00$). No significant interaction between gender and device was found ($p > 0.05$). Post-hoc analysis showed differences ($p \leq 0.05$) between the devices. The pGRF of the un-affected limb was highest for the CC (1070.54 ± 319.87 N), second highest for the HFC (956.80 ± 195.89), and lowest for the KR (590.38 ± 198.43). Differences ($p = 0.045$) in pGRF were found for the affected limb between the KR (701.63 ± 121.33 N) and the HFC (651.77 ± 135.15 N). The ICC's for the test exercises and all dependent variables ranged from 0.90 to 0.99.

Results of the qualitative analysis revealed that both men and women identified underarm discomfort (N=11), and ease of use with experience (N=10) as the main disadvantages and advantages, respectively, of using the CC. Men indicated that the KR require little effort (N=9), while women found it to be difficult to maneuver (N=6). Both genders identified difficulty transporting the KR as the main disadvantage (N=6). Both genders found the HFC to be unstable (N=16), with men also reporting it was impractical (N=6), and women describing it as uncomfortable (N=6). Tables 1 and 2 identify additional advantages and disadvantages of these ambulatory assistance devices.

Table 1. Qualitative Advantages of Ambulatory Assistance Devices

	KR	N	CC	N	HFC	N
Men	Effortless	9	Most Practical	6	None Identified	0
	Mobility	6	Ease of Use	5		
	Enjoyable	5	Easier than HFC	3		
	Stability	2	Easy to Balance	2		
Women	Ease of Use	6	Preferable	4	None Identified	0
	Minimal Strain	4	Little Difficulties	4		
	Comfortable	4	Quick Mobility	2		
	Enjoyable	3	Efficiency	2		

Table 2. Qualitative Disadvantages of Ambulatory Assistance Devices

	KR	N	CC	N	HFC	N
Men	Transportation	3	Underarm Soreness	5	Hard to Use	6
	Affected Limb Pain	2			Balance Issues	6
					Effort Needed	4
Women	Difficult to Maneuver	6	Underarm Soreness	6	Balance Issues	8
	Transportation	3			Small Base of Support	7
	Compromised Gait	2			Discomfort	6

DISCUSSION: This is the first study to compare the HFC to other devices such as the CC and the KR, and to assess the kinetics in addition to the subjective experience with each device. Results show that the pGRF of the un-affected limb was highest for the CC, second highest for the HFC, and lowest for the KR. More specifically, for the un-affected limb, the CC produced approximately 45% and 11% more kinetic demand than the KR and HFC, respectively. The higher pGRF associated with the use of the CC for the un-affected limb is likely due to the fact that only the CC eliminates all weight bearing from the affected limb. This may also explain the underarm discomfort reported by some subjects while using the CC. For the affected limb, the KR produced approximately 7% greater demand than the HFC, potentially due to the dynamic transfer of weight and inertial forces loading the affected side, in reaction to the propulsive forces of the un-affected leg during the use of the KR. Other research rarely assessed GRF in the comparison of ambulatory assistance devices. One exception is a study demonstrating somewhat dissimilar results, where GRFs were lower for CC and forearm crutches and higher for wheeled devices, potentially due to the study goals of training the subjects to achieve a 50% weight reduction during the use of CC and forearm crutches (Youdas et al., 2005). While differences in GRFs have seldom been studied, differences in gait patterns have been shown (Hardi, 2014). Other evidence demonstrated energy expenditure was higher for CC and lower for KR (Patel et al., 2016).

No interaction between gender and device was found in the current study. Thus men and women's kinetic experiences with these devices are similar. No other study assessed gender differences between ambulatory assistance devices.

Results of the qualitative analysis revealed that both men and women identified under-arm discomfort and ease of use with experience as the main disadvantages and advantages,

respectively, of using the CC. Men indicated that the KR require little effort, consistent with research showing lower perceived exertion and a preference for the KR (Kocher et al., 2016), and lower energy expenditure than CC (Patel et al., 2016). However, women subjects in the current study found the KR difficult to maneuver. These findings are consistent with concerns presented in a systematic review of walking aids, which concluded that walking aids facilitation of mobility depended on the user's ability to overcome their obstacles (Bertrand et al., 2017). In the present study, both men and women identified difficulty transporting the KR as the main disadvantage. Both genders found the HFC to be unstable, and several men reported it was impractical while several women described it as uncomfortable. These findings are in contrast to a quasi-experimental study in which a HFC was reported easy to learn and use (Rambani et al., 2007), with only minimal issues such as the development of knee and back discomfort.

Research assessing ambulatory aids may produce different results when using subjects with lower limb pathology and more experience with the KR and HFC. Thus, future research in this area should consider the use of subjects with experience with these devices and those with impaired lower limbs.

CONCLUSION: This study shows that the pGRF of the un-affected limb was highest for the CC, next highest for the KR, and lowest for the HFC. The pGRF of the affected limb was higher for the KR compared to the HFC. The qualitative analysis showed that the CC and KR were favored over the HFC, despite the underarm discomfort reported by some subjects while using the CC. Difficulty with balance and use were identified as the biggest disadvantages of the HFC.

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